NAVAL RESEARCH

REVIEWS

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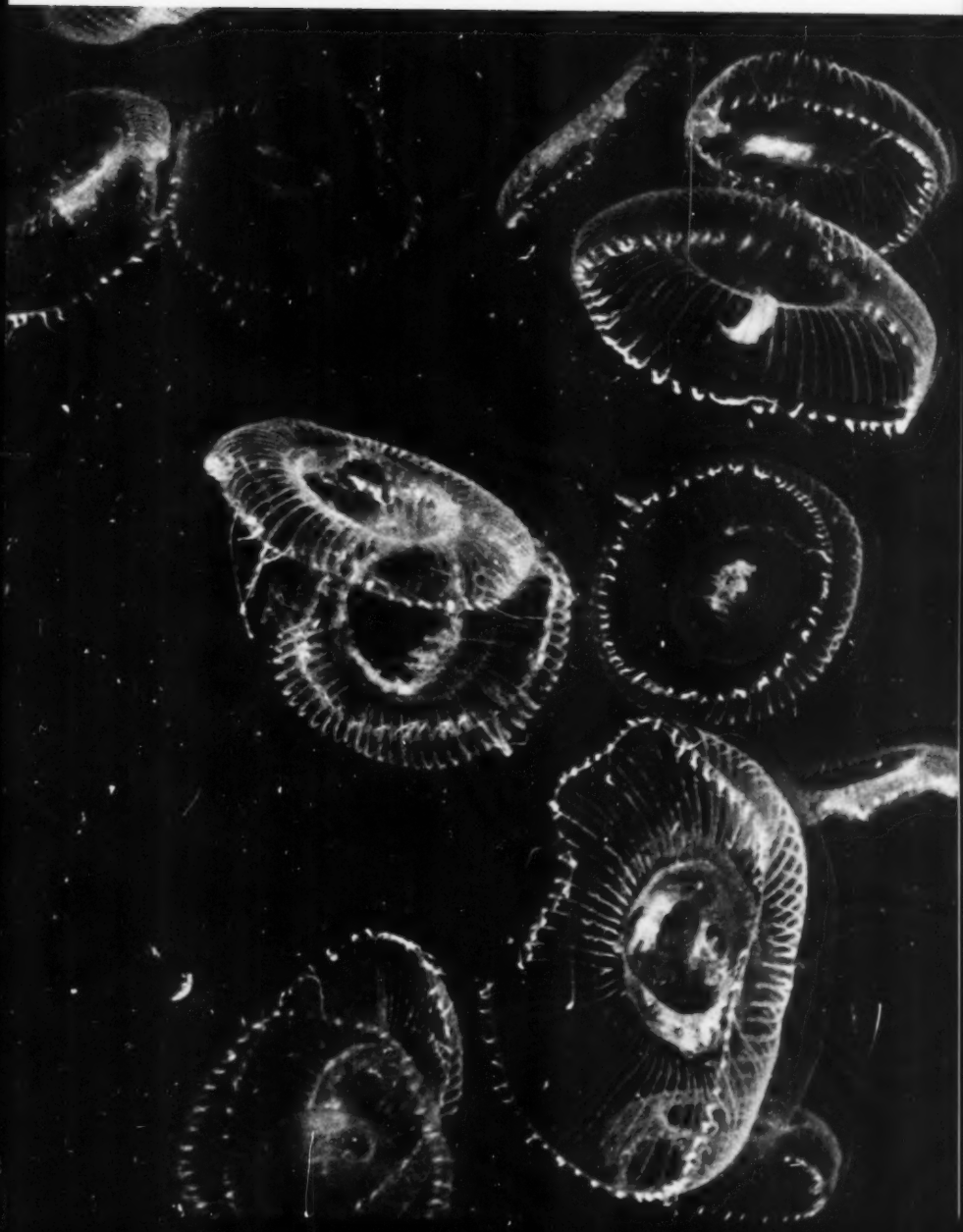

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Portraits in Science

DR. KERN IS AN AUTHORITY IN THE FIELD OF ALLERGIES, TROPICAL MEDICINE, AND INFECTIOUS DISEASES. AFTER COMPLETING HIS MEDICAL DEGREE, INTERNSHIP, AND RESIDENCY AT THE UNIVERSITY OF PENNSYLVANIA, DR. KERN CONTINUED AT THE UNIVERSITY, BECOMING PROFESSOR OF CLINICAL MEDICINE. IN 1946 HE BECAME HEAD OF THE MEDICAL DEPARTMENT AT TEMPLE UNIVERSITY FROM WHICH POST HE RETIRED IN 1956. DR. KERN WAS A NAVAL OFFICER IN THE TWO WORLD WARS AND RECENTLY RETIRED AS AN ADMIRAL IN THE MEDICAL CORPS OF THE NAVAL RESERVES. DR. KERN WAS A CONSULTANT TO THE SURGEON GENERAL OF THE NAVY AND SERVED MANY YEARS AS A MEMBER OF THE NAVAL RESEARCH ADVISORY COMMITTEE.

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The Sponsorship of Basic Research*

Arthur R. Laufer
Office of Naval Research
Pasadena, California

I congratulate you on your election to Sigma Xi. Since one of the primary objectives of the Society of Sigma Xi is "the encouragement of scientific research," I thought it would be appropriate to speak to you this evening on what is a relatively modern phenomenon in the long history of science, the federal government's sponsorship of basic research in universities. The mutual dependence between the government and the universities in the field of research is one of the most profound and significant developments of our time.

Considering that this is Sigma Xi and that this is Cal Tech, it is safe to predict that most of you will go on to graduate work and will become scientists of one kind or another. This will make you a member of a unique species. According to a recent psychological study, the typical scientist is "highly intelligent, individualistic, radical, retiring and unsociable, generally unhappy in his home life, and married to an unattractive woman." I must say I question the validity of this assessment – most of the scientists I know are not retiring and unsociable.

After you become professional scientists with the Ph.D. union card, most of you will want to continue to do research. I say "most" only because, again, this is Sigma Xi at Cal Tech; Derek de Solla Price of Yale has gathered statistics which show that, in the country at large, 60 percent of the research scientists with graduate training through the Ph.D. publish only one research paper and then are never heard from again. For many, the Ph.D. degree is merely a guarantee of a higher starting salary. However, most of you who are here tonight will continue to do research, and today research requires money, often much money.

Since most organizations, especially universities, have very little free money which can be used to support research, you will have to find a sponsor. I have heard a sponsor described as "a large body of money completely surrounded by outstretched hands." Whereas it is true that the body of money is extremely large, amounting altogether to billions of dollars, the number of outstretched hands is also extremely large and is increasing at a startling rate. de Solla Price claims that the number of scientists, journals, and published papers have all been doubling every 15 years; each time the general population doubles, the scientific population increases 8-fold. The general population explosion is thus only a small "pop" compared to the scientific explosion.

*A lecture given at the Annual Initiation Ceremony of Sigma Xi at the California Institute of Technology, 15 May 1969. Sigma Xi is an honor society for scientific research.

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Thus, in the future it will become increasingly difficult for you to find a sponsor for your research, and this will be one of the major problems to be faced by the universities in the coming years.

Tonight I would like to describe the circumstances through which the federal government became the major sponsor of research in the universities, and to discuss various implications of the present system of research support. I must of course make the usual disclaimer to the effect that any opinions I express are completely my own and do not necessarily represent the views of the Department of Defense. However, I am not prepared to promise that none of my remarks will be controversial.

The present total expenditure on research and development in this country is truly impressive. In the current fiscal year, the total expenditure will be about 27 billion dollars. Industry will perform over 19 billion dollars worth of this R&D, government laboratories will perform about 3-1/2 billion, and universities and other non-profit institutions will perform about 4 billion. The federal government contribution to this 27 billion dollars will be about 17 billion. These figures cover all of research and development, of course, but even the fraction devoted only to basic research in universities is impressive: in this fiscal year it will amount to almost 2 billion dollars.

This 2 billion dollars is for what I have labelled basic research. What do we mean by "basic" research? The late, well-known and rough-spoken industrialist Charles F. Kettering, who was vice president of General Motors and invented the automobile self-starter, defined basic research ungrammatically as "something that if you don't do it until you have to, it's too late." The National Science Foundation defines basic research as "the search for an understanding of the laws of nature without regard to the ultimate application of the results." The Department of Defense defines it as "that type of research which is directed toward an increase of knowledge in science. In such research, the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than any practical application thereof." A typical industrial definition is "original investigations for the advancement of scientific knowledge that do not have specific commercial objectives." Some academicians call it "pure" science, thereby making a value judgment, and some cynics call it "useless" science, another value judgment. I have read a statement made about five years ago by Sir John Carroll, then Chief Scientist to the British Admiralty, in response to a demonstration of a new basic research result: "The ingenuity of your innovation nearly blinds me to its utter uselessness."

As a matter of fact, whether a given research project is basic or applied is in the eye of the beholder. It often may be either, depending on the motives of those conducting the work and those sponsoring the work, and, furthermore, it may be basic for one of these and applied for

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the other. Sometimes it appears as though basic research is something you yourself choose to do, and applied research is something someone else tells you to do. It is primarily a matter of semantics and viewpoint, with a tinge of snobbishness since in the hierarchy of science, pure research is claimed to stand higher than applied research.

But how did this overwhelming involvement of the federal government in academic science begin? Clearly, it is a modern phenomenon. The Constitutional Convention of 1787 explicitly rejected efforts to grant the federal government constitutional authority for the pursuit of scientific inquiry. Not science, but only patents are mentioned in the Constitution. Responsibility for the welfare of science was a much later established role of the federal government.

In 1862, one year after the first American Ph.D. was awarded (at Yale), Congress passed the Morrill Act, which granted public lands to the states to be sold and the money recovered to be invested and its income used to maintain at least one college "where the leading object shall be, without excluding other scientific and classical studies and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts." In 1887 the Hatch Act was passed to provide federal funds for the support of university research in agriculture. The agricultural and mechanical phase of the universities lasted until World War II. The pace of scientific progress was slow in the 19th century. It was in those years that Tennyson wrote, in Locksley Hall, "Science moves, but slowly, slowly, creeping on from point to point."

In the years prior to World War II, the federal government supported some science, but outside of agriculture and some geology, very little in the universities. It supported the Smithsonian, the National Bureau of Standards which was founded in 1901, the Coast Survey, the Bureau of Mines, the Public Health Service which was founded in 1912, the National Advisory Committee for Aeronautics (NACA), founded in 1915, and a number of other activities, but the total investment in science was small. In those days, funds for university research came from a number of highly selective philanthropic foundations and from the meager operating funds of the universities themselves. Those were the days of what we now call "little" science, the days of "sealing wax and string," the days when a cyclotron could be built for $50,000 with the aid of professorial labor, the days when there were no ONR research assistantships and no NSF fellowships. I began my graduate work toward the end of those days, and whereas they were peaceful and productive, I would not call them the "good old days."

Then war came to Europe and the question arose as to whether science in this country could be mobilized in our own defense. It was an historical accident that most of the nation's most competent scientists at that time were on university faculties, a situation which was different from

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that in most European nations. It was therefore necessary to try to develop a mechanism for using the scientific talent in the universities, even though no tradition of substantial government support of university research had previously been established.

The mechanism was suggested to President Roosevelt by Vannevar Bush, President of the Carnegie Institution and Chairman of the NACA, james Conant, President of Harvard, Karl Compton, President of MIT, and Frank Jewett, President of the Bell Telephone Laboratories and also President of the National Academy of Sciences. In 1940 Roosevelt established the National Defense Research Committee (NDRC) to "conduct research for the creation and improvement of instruments, methods, and materials of warfare." A year later, also by Executive Order, Roosevelt established the Office of Scientific Research and Development (OSRD), which included NDRC but also extended jurisdiction over medical research, over coordination of research being done by the Army, Navy, and NACA, and over development work on weapon systems. OSRD, which was headed by Vannevar Bush, provided support for scientists doing research judged important to the national security at their own universities, and where large concentrations of scientists were needed for large problems, organizations were created such as the Radiation Laboratory at MIT, headed by Lee DuBridge, where very successful R&D on radar was conducted.

Most of this research was, of course, applied research and war-related. A very large number of university scientists were involved. Great technical advances were made, and the results of organizing the scientific potential of the nation were dramatic. However, OSRD was a temporary war-time organization and went out of existence automatically at the end of the war in 1945.

Even before the end of the war, many influential people felt that it would be unwise to allow science, after the war, to slip back to the level of pre-war scientific activity. This feeling was expressed by President Roosevelt in 1944 as follows: "The information, the techniques, and the research experience developed by the OSRD and by the thousands of scientists in the universities and in private industry should be used in the days of peace ahead for the improvement of the national health, the creation of new enterprises bringing new jobs, and the betterment of the national standard of living."

These general feelings were given coherent expression in 1945 in the report of a special presidential committee of distinguished scientists, educators, and industrialists, headed by Vannevar Bush. This report, entitled *Science—the Endless Frontier*, provided a blueprint and a timetable for the postwar expansion of the federal support of science. The creation of a new government agency, the National Research Foundation, was proposed as the principal means for carrying out the major recommendations of the report. The Foundation would

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support basic research, on a large and increasing scale, primarily at universities. It would be headed by a Board of part-time non-government people which would appoint the Director and establish policy.

This report had great impact on the public and on the Congress. However, two years earlier Senator Kilgore had developed a plan for a central scientific and technical body which was slanted toward the support of industry. Kilgore now introduced his own bill, and Senator Magnusen introduced a bill embodying the Bush concepts. President Truman insisted on a single agency and objected to a board of private citizens expending and controlling federal funds, as would the Board of the proposed National Research Foundation. There were some who wanted a certain precentage of the funds of the Foundation reserved only for land-grant universities. Questions concerning the ownership of patents were raised. Delay after delay ensued, but the Magnusen bill eventually triumphed and was passed by Congress in 1947—only to be vetoed by Truman.

Years of additional negotiation followed. It was not until 1950, five years after the end of the war and the end of OSRD, that a bill was finally passed and signed by Truman, establishing the National Science Foundation, with both the Director and National Science Board to be appointed by the President. Its initial appropriation was only $225,000 for 1951, and its total disbursement of funds for research grants in the 2-year period 1952-1953, seven years after the end of the war, was only $2,750,000. This was a far cry from the high hopes expressed during the war. This funding was not nearly enough to prevent science from slipping back into the pre-war "sealing wax and string" days. Not until 1957, following Sputnik, was the NSF budget raised to the level proposed in 1945.

However, I am pleased to say that the United States Navy was standing in the wings, ready, willing, and able to save the day. For many generations in the past the Navy had had a strong interest in science. The Navy needed accurate astronomical observations for navigation and therefore in 1834 set up this country's first installation devoted entirely to astronomical observation; in 1841 this institution was officially established by Congress as the Naval Observatory in Washington. From 1838 to 1842 the Navy mounted the first major national effort in exploration, the Wilkes expedition, a voyage which ranged from the Central Pacific to the Antarctic; this was the first time that professional scientists were used in exploration. On this cruise they charted unknown seas, made celestial observations, and went as far as the Antarctic ice barrier to prove the existence of a continent beyond. Admiral Peary went to the North Pole, Lt. Matthew Fontaine Maury made the first application of scientific methods to navigation, and an ensign named Albert Michelson performed experiments at the Naval Academy on the velocity of light. Michelson's initial efforts culminated some years

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later at the University of Chicago in the Michelson-Morley experiment which was the basis for the eventual development of relativity theory. Michelson, the Naval Academy graduate, was America's first Nobel Prize winner in physics. The second, of course, was your own Robert Millikan, who worked with Michelson for a time at Chicago.

Another relationship of the Navy to science is revealed by its involvement in the formation of the National Academy of Sciences. In 1862 Commodore Charles Henry Davis, Chief of the Navy Bureau of Navigation, proposed a "Permanent Commission" to provide the Navy with information on "questions of science and art." He won strong support for this idea from scientists, and the Permanent Commission was established by the Secretary of the Navy in 1863. Davis urged the scientists to ask Congress to form a National Academy of Sciences, his instinct telling him that the time for this was ripe. Within a month, Congress passed the bill and President Lincoln signed it.

The Naval Research Laboratory was the Navy's contribution to science in World War I. When war erupted in Europe, this country had no central military research organization. In July 1915 the New York Times published an interview with Thomas Edison in which he stressed the need for a research agency within the Navy. On that same day, Navy Secretary Josephus Daniels wrote to Edison asking him to head a board to plan such an agency. A year later the board proposed the establishment of a naval research laboratory, and Congress approved it and provided funds. The range of its research interests was and is broader than that of any other research agency in the DoD. Thus the Navy was already a strong supporter of science when we entered World War II.

During the war, a group of young scientifically-trained Naval officers began to worrying about what would happen to research at the end of the war when OSRD was scheduled to go out of existence. The scientists would return to their academic work and the tremendous scientific momentum built up by OSRD would be lost if no way were found to provide support for peacetime research. These officers, with the support of a group of eminent scientists, succeeded in persuading the Navy to respond to the problem. By executive order, Secretary of the Navy James Forrestal in 1945 established the Office of Research and Inventions, which merged several Navy research organizations, including NRL, into a single centralized agency. At this time the Congress was embroiled in the bitter arguments concerning the establishment of the National Science Foundation, and it was apparent that a civilian research-supporting agency would not be established by the time it was needed. The Navy was determined not to allow OSRD's research momentum to be dissipated, and a bill for the establishment of an Office of Naval Research, which was to absorb the Office of Research and Inventions, was drafted and submitted to Congress. The Vannevar Bush report,

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Science—the Endless Frontier, was issued at that time, and although it was not successful in persuading Congress to immediately establish the National Science Foundation, its impact was so great that Congress did establish the less-controversial Office of Naval Research. Public Law 588, passed on August 1, 1946, and signed by President Truman on August 3rd, established the Office of Naval Research as a part of the Office of the Secretary of the Navy, with statutory authority for conducting a broad program of scientific research under contracts with civilian organizations. Thus, as the result of its own far-sighted planning and the favorable action of Congress, the Navy found itself the sole government agency with the power to move into the void created by the phasing out of the OSRD. Furthermore, and strangely enough, although the civilian OSRD was concerned primarily with applied war-related classified research, the military ONR was to be concerned primarily with basic non-war-related unclassified academic research. ONR arranged for war-end money transfers, obtained an appropriation of $45 million in 1947, and during the next four years, while Congress still debated what to do about a civilian research agency, ONR moved forward aggressively to bridge the gap. The world leadership of the United States in basic research in the decade following World War II has been credited by many to the timely and effective action of the Navy.

As the first permanent federal agency to be given considerable resources for supporting research in universities, it was necessary for ONR to develop a new type of contract which would be acceptable to the universities and would still protect the government interest. Some universities were fearful that federal support would mean federal control, and that onerous restrictions of various kinds would be imposed. ONR developed a system which invited the submission of unsolicited proposals, in lieu of the time-honored bureaucratic system of competitive bidding. The principal product of the contract was acknowledged to be a report or preferably a paper in a scientific journal, rather than hardware. The contract was to be monitored with official restraint and a minimum of reporting. These features, which seem natural now, were revolutionary in 1946. This display of understanding of the nature of research and of the latitude necessary in the contractual relationship won over the scientific community, and ONR was deluged by a flood of proposals. By 1949 ONR had 1200 contracts in 200 institutions, engaging the efforts of 3000 scientists and 2500 graduate students. The provision for the support of graduate students as research assistants to the principal investigators was a significant innovation.

When the AEC and the NIH began contracting for research, and when the NSF and later the Air Force Office of Scientific Research, the Army Research Office, and the NASA were established and undertook their research-supporting efforts, the ONR policies served as their model. Many of the science administrators who shaped, and were shaped by,

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ONR in its early years left to take important positions in the newer agencies. For example, Alan Waterman, the first Chief Scientist of ONR, became the first Director of the National Science Foundation. The process of direct transfusion accounted in part for the pervasiveness of ONR's influence on government-science relationships.

In the following years ONR supported a broad spectrum of scientific research programs in all of the sciences: physics, mathematics, astronomy, oceanography, chemistry, biology, psychology, and so on. Here at Cal Tech we have supported many projects for many years, including Carl Anderson's work in cosmic rays, the Lauritsen-Fowler work on low-energy nuclear physics and nuclear astrophysics, the Owens Valley Radio Observatory, and even much of Linus Pauling's work on proteins.

Today, although the Office of Naval Research still has about 2000 contracts, it supports only a fraction of the on-going research in the country. The emergence and growth of the other support agencies have greatly expanded the research effort of the country, and whereas ONR is still very important in the Navy, it occupies a relatively minor role in the big picture. Nevertheless, the results of its early influence are still being felt. Perhaps the most important contribution of ONR for the long run was its successful demonstration of how the government can lead and encourage the performance of basic research without submerging it in a stultifying bureaucratic maze.

On the occasion of the dedication of the Owens Valley Radio Observatory in 1961, Dr. Lee DuBridge said: "To ONR, the scientific world owes an enormous debt of gratitude for pioneering the way in which the government could assist the universities in the prosecution of the search for basic knowledge and the training of graduate students in scientific and engineering pursuits, and these techniques have been widely copied in other agencies of the government today."

In 1966, on the occasion of the vicennial celebration of ONR's birth, Professor Harvey Brooks of Harvard said: "As one reviews the history of American science and technology in the last 20 years, one cannot fail but be struck by the strategic role which ONR-sponsored work has played. In fact, when one considers its present minor fiscal role in research support compared with what it was in the early days, one is surprised at its still major importance and influence. Wherever the most important advances are being made, one still seems to find ONR present with at least some support. A catalog of areas in which ONR-sponsored scientists have pioneered shows how frequently ONR has been there with the right science at the right time, even though few foresaw the usefulness and relevance when ONR first began to sponsor it.

I hope you will realize that I am quoting these statements, with such an unseeming lack of modesty, in order to make a point. This point is that the existence of a number of different mission-oriented research-sponsoring agencies, of which ONR is only one, each with its own

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motivation, is good for science. There are some who would like to see all university research supported by a single super agency, in part to achieve administrative neatness. Such a system would be fraught with many dangers.

Most of the best scientific talent in the country resides in the universities. The various mission-oriented agencies of the government, NIH, AEC, NASA, and the military services, have urgent need for this talent to assist in the solution of our many national problems ranging from the conquest of disease to the provision of an adequate national defense. A single monolithic agency cannot be relied upon to have the wisdom needed to support in sufficient depth the various areas which are of overriding importance to the missions of the other agencies.

Another aspect relates to the independence of the scientist. The most important feature of his independence is that he can decide for himself what research he wishes to do. After reaching this decision he prepares a proposal and submits it for support. In each agency a very small group of administrators and advisors decide, in each area of science, which proposals will and which will not be supported. In a monolithic system, the scientist would have but one chance; if his proposal were rejected, he would be through, unless he reformulated his proposal for another scientific subject or for another approach, all this with a consequent loss in his independence. In our present pluralistic system, the same scientist has several chances to obtain support. If he is turned down by one agency, he can apply to another. In fact, today many scientists apply simultaneously to a number of different agencies in the hope of arousing the interest of at least one of them.

The diversity and the mixed-decision aspect of our present system for the support of academic research is probably the greatest source of our scientific and technical strength. Our scientific choices are now governed by a wide diversity of priorities, environments, and motivations, leading to a strong and flexible system. There is no single best way to support science and the health of American science undoubtedly derives in large measure from its diversity. The fears of federal control coming with federal funds have proved unfounded, perhaps largely because the funds have been injected through a variety of agencies for a variety of purposes. The multiplicity of alternative sources of support is, I believe, one of the most important safeguards for the independence of the individual scientist.

Still another aspect of this problem relates to the provision by Congress of adquate funding for science. You all know that the Congress has treated NSF rather brutally in the past few years. Certain other agencies, however, have been able to better cope with the Congressional economy moves and with Congress's apparent loss of confidence in the worth of basic research. A monolithic science-support agency would be highly

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vulnerable to Congressional action. The mission-oriented agencies can often provide justifications for the support of science which are more easily understood by our legislators than are the justifications for "pure" science.

Consider another danger in the monolithic support of science. Every agency must plan its program to match the available funds and to attempt to place its support in areas which are likely to prove productive. This "planning" is given magical significance by many who face the nation's staggering problems and seek any available handle to aid in their solution. Unfortunately, no one knows how to plan. Let me give you a few examples.

Dr. John Foster, Director of Defense Research and Engineering, testifying before the Senate Committee on Armed Services last year, said: "Those who in the past have tried to predict the future of science have usually been far too conservative. For example, one technical forecast in 1937 missed computers, atomic energy, antibiotics, radar and jet propulsion. Yet all of these were incorporated in successful systems within a few years after the forecast."

Another example. Dr. Vannevar Bush, whom I mentioned earlier as the Director of OSRD, was also Chairman of the Joint Committee on New Weapons of the Joint Chiefs of Staff. In testimony before the Special Senate Committee on Atomic Energy in December 1945 he said: "Let me say this. There has been a great deal said about a 3000-mile high-angle rocket. In my opinion such a thing is impossible...The people who have been writing these things that annoy me have been talking about a...rocket shot from one continent to another carrying an atomic bomb, and so directed as to be a precise weapon which would land on a certain target such as this city. I say technically I don't think anybody in the world knows how to do such a thing and I feel confident it will not be done for a very long period of time to come. I think we can leave that out of our thinking. On the same subject, Frank Malina said last year that in 1936 Clark Millikan was dubious about the future of rocket propulsion, and that in 1938 a senior Army officer on a visit to Cal Tech stated there was little possibility of using rockets for military purposes!

Since this is Cal Tech, let me quote another Millikan to you, this time Robert Millikan. In the 1930s, in answer to an English bishop's proposal that a 10-year moratorium be imposed on research to allow civilization time to cope with its creations, Millikan said: "The bishop need not worry about science, or about the absurd possibility that mankind, armed with the energy of the atom, might blow itself to kingdom come. That energy is destined to stay locked in the atom. The Creator has put some foolproof elements into his handiwork and...man is powerless to do it any titanic damage." Similarly, in 1933, Lord Rutherford, the father of nuclear physics, said: "Anyone who expects a source of power

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from the transformation of the atoms is talking moonshine." Dr. Karl Darrow published a paper presenting five reasons why Nature would never allow a chain reaction to take place. Then in 1938, only five years after Rutherford's pronouncement, nuclear fission was discovered by Hahn and Strassman, and in 1942 a chain reaction was achieved by Fermi.

Let me give just one more example out of the hundreds which are available, this one again involving Cal Tech. At the Thirteenth Joseph Henry Lecture delivered to the Philosophical Society of Washington in 1944, on the subject "Faster Than Sound," Theodore von Karman said: "Obviously, it is an intriguing question whether there are any intrinsic limits for flight velocity. Many people will ask 'Shall we ever fly faster than sound?' I do not believe that at the present this question can be answered by a straight yes or no." In the same lecture he said: "To some extent the question of supersonic flight is analogous to another intriguing problem discussed sometimes by serious men, more often by authors having more imagination than scientific knowledge. I mean the question of the feasibility of navigation off from the gravitational field of the earth. Of course, some fabulous new fuel would change the situation completely in both cases. However, basing the consideration on power plants and fuels which are available or which we hope to have with reasonable expectation, the answer to the question of the feasibility of planetary navigation is probably negative." Parenthetically, he closed this lecture with the following remarks: "We did not touch on one question at all, a question that perhaps is fundamental: Why does anyone want to travel so fast? I think this question is too difficult for an engineer. It should be asked of a philosopher." This talk was given in April 1944; on October 17, 1947, Captain Charles Yeager of the Army Air Force flew the Bell X-1 rocket research aircraft at supersonic speed in level flight. One should also not forget that in the 1890s a Bishop Wright said that God did not mean for us to fly—if He had, He would have given us wings. Bishop Wright had two sons, named Wilbur and Orville.

Now, let me assure you that I have not presented these examples to deride a number of eminent and extremely competent scientists of the past. I am merely seeking to show that none of us, not even the best of us, is very competent in predicting the future. And this is why planning fails and cannot help but fail. As Edmund Burke wrote, "You cannot plan the future by the past." If a man like von Karman, in his own science of flight of which he was the greatest practitioner, did not have sufficient intuition to be confident that we would pierce the sound barrier and that we would send vehicles to the moon and to Mars, what hope have the rest of us who are involved in planning for the future of science and are equipped only with 20-20 hindsight? We would be better off to listen to the "authors having more imagination than scientific

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knowledge," as von Karman put it, and to put faith into the predictions of Jules Verne and H. G. Wells.

Obviously, my thesis is that we don't know how to plan, that, as in the search for happiness, the search for new technology is often best approached by indirection, and that a decentralized pluralistic decision-making system such as we now have, with a multiplicity of research-sponsoring and -planning agencies, provides us with a redundancy which serves to minimize the harmful effects of high-level planning.

Finally, I would like to make some reference to the current attempt by certain segments of the academic community to force the termination of all defense-related research on university campuses. I have great sympathy for those young people who are dissatisfied with the state of the world, who would like to see science more deeply involved in socially constructive activities, who are concerned about the uses to which science is being put, and who have a hunger to make science relevant and benign. Some of them worry that, as Winston Churchill put it, "the Stone Age may return on the gleaming wings of Science."

However, the elimination of defense-related research from the campus would not solve the problems they wish to see solved, and would introduce certain new problems, which they have apparently not foreseen.

First, most of the research supported by the DoD on university campuses is what we have defined as basic research. But not only the DoD benefits from this research; the so-called "socially constructive" agencies benefit at least as much. For example, ONR pioneered and developed techniques for preserving whole blood for relatively long periods of time by means of rapid freezing techniques. Whereas it is true that such preserved blood is of great medical value for military personnel aboard ship and on battlefields, many more civilians will benefit from the resulting improvement in operation of blood banks throughout the country. On the other hand, there are many cases in which the results of NSF-supported research have been used by the military for less humanitarian purposes. The fact is that the results of free and unhampered basic research, freely published, may be used by any agency of society for whatever purpose. A scientist seeking support for basic research from a particular agency does not necessarily share the motives of that agency. He has his own, presumably lofty, motives for undertaking that research. Similarly, if the research is truly basic, it would be difficult for him to assess the ultimate social consequences of his work, whoever the sponsor might be. It appears to me that it is the nature of the research which is important, not the identity of the sponsor. Hence, forcing DoD research off campus into research institutes and industrial laboratories will not prevent the DoD from benefiting from the non-DoD research which remains on campus, but will deprive the faculties and graduate students of hundreds of millions

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of dollars of research support which is sorely needed for both scientific and educational purposes.

If DoD research were forced off campus, there is no assurance that the scientists on campus would turn their efforts to those social problems which concern the dissidents. The National Academy of Sciences, in a 1967 report on "Applied Science and Technological Progress," stated that "In the mobilization of technical effort around significant problems of society, it must be borne in mind that the highest-quality technical people cannot be drawn into projects on the basis of the alleged social importance of the problems. They must be able to see an opportunity for making concrete, identifiable contributions that relate to their particular talents and background." The reason why many scientists apply for DoD support is that the basic science problems which the DoD will support are, comparatively speaking, easy problems, which the scientists know how to attack. The social problems of racial intolerance, urban congestion and decay, pollution of the environment, and international tension and conflict, depending as they do on the preferences, desires, and emotions of human beings, do not appear to be amenable to solution by the techniques which scientists know how to employ. Some time ago, a group of systems specialists representing a wide variety of technological disciplines gathered at the RAND Cooperation for several weeks to study how their talents could be applied to some of the more urgent urban problems. The study ended in an aura of gloom and despondency because the scientists found, despite their high initial hopes, that they not only could not readily apply their systems techniques to the problems considered, but that they could not even adequately formulate the problems. The technical solutions of many social problems are already at hand—all they require for successful application are societal changes such as changes in economic systems and changes in the hearts of men. Under such circumstances, the departure of the "easy" scientific problems of the DoD from the campus might lead some of the most competent scientists and engineers to follow this research off the campus, to the detriment of the university.

It is clear that our American society places a very high value on military strength for defense—witness the size of our defense budget. Most Americans believe that our country cannot rely for survival upon purely ethical superiority in a world which includes the Soviets and Czechoslovakia, the Biafrans and the Nigerians, Israel and the Arab countries, and mainland China. Even the prolonged Vietnam war has not made America feel that defense is dishonorable and unethical. Of all the unforgivable things the Department of Defense might do, in the veiw of most Americans, the most unforgivable would be to allow this nation to be conquered through a technological surprise. They have

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not forgotten what the world not would be like if Adolph Hitler had been the first to create the atomic bomb. Thus defense research is now and will long be, I am afraid, an integral part of our society. It is therefore difficult to understand how those students who want the university to become *involved* in the problems of society, to come down from the ivory tower, now can demand that the university eliminate its involvement in one of the most serious problems of our society.

Perhaps the students also do not realize that such disengagement would deprive society of an important safeguard (if you will excuse the word). The record shows that university scientists have consistently led efforts to awaken our society to the dangers of the misuse of technology, of the arms race, of the pollution of our environment, and so forth. Their participation in agency-related work provides an independent standard of criticism of public policy. Increasingly, major national decisions must be made on issues that involve considerable scientific or technolgical complexity, and therefore government agencies and their industrial contractors often have a near-monopoly on the relevant information. The university provides the primary locus in our society for critical examination of social issues from a base of strong analytical capability and a base relatively independent of the government and its policies. If the university were to withdraw from the agency-related work and remain aloof, who else would be available to make independent analyses and challenge the government positions on complex technological questions? Who would be available to refuse to accept the usual assurances and justifications? Is not defense research also too important to be left to the generals and the admirals?

Years ago, the DoD and the AEC supported university research on the atmospheric effects of nuclear weapons, such as fallout and shock waves. The scientists involved in these studies played major roles in the decisions which led to the nuclear test-ban treaty. Today, the university scientific community is playing a dominant role in the discussions of the ABM. Scientists such as Hans Bethe of Cornell, Kistiakowsky of Harvard, and Wiesner of MIT, all former ONR contractors, have raised the level of sophistication of the debate and have provided the challengers of the ABM with the kind of independent informed technical backup which would not have been possible if they had not been involved in the activities of the DoD. By isolating the university campus from the Department of Defense, the dissidents would in effect be joining hands with those special interests which have been labelled the military-industrial complex.

Unfortunately, as McGeorge Bundy said in his book, *The End of Either/Or*, "what makes debate so easy and action so hard...is that the debater can defend those propositions he likes from a great pile of evidence in which there is plenty to support every view. In our actions, however, we have to live with the whole." Many of the campus

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dissidents appear to be practicing what Reinhold Niebuhr called "the strategy of fleeing from difficult problems by taking refuge in impossible solutions." The greatest tragedy of the present campus disorders is that, as Will Durant said, "When liberty destroys order, the hunger for order will destroy liberty."

Perhaps some of my remarks have taken the form of moral preachments, but you young scientists who will soon enter the arena will have to consider these questions for they will affect your conduct, your lives, and the future of your country and the world.

Computer Information Protection and Sharing

While information sharing across a group of system users has always been a major goal of modern time-sharing technology, limited capabilities to exercise control over what is to be shared or protected from sharing has inhibited full realization of the stated objective. If one accepts the precept that information sharing must be voluntary, then encouragement of this aspect of time-sharing can only be effective if we develop mechanisms to permit users to exercise selective control over the contents of their data bases. Unfortunately, developments to date have restricted control to the file level; that is, one can permit or prohibit access to an entire file—one cannot invoke sharing rules to operate on individual items within the file.

Recent progress under the ONR contract at the University of Pennsylvania has resulted in the design of the first operational data management system which facilitates control at both the record and field level. With this capability, file owners are afforded the full range of desirable sharing and protection features. User entry into the system can be invited to the full content of a given file or files; at the same time, selected records or fields can be closed to all users, or to a specified group of users, or even to an individual user.

To provide a simple example of this capability, assume a file of medical records; each record consisting of a patient's name and all of the medical history associated with that name. Protection at the file level implies access to or denial of access to all records within the file. Protection at the record level permits identification of certain patient's whose medical records will be denied to all but a designated group of users. Protection at the field level permits the file owner, for example, to hide the patient's name, but to permit entry to all statistical information inherent in a data base of medical histories.

The important aspect of this development is that through this breakthrough in file management, system users, given confidence in their ability to protect information, will also increase in their willingness to share information. Both of these factors, computer information protection and sharing, are essential to improving communications across agencies and decision makers in the fields of intelligence, command and control, and logistics.

ONR Simulator to Navy Lab

During a long-term effort in Geographic Orientation conducted for ONR/JANAIR by Human Factors, Inc. a mobile laboratory was produced. This laboratory, constructed in a van, contains a briefing room, projector room, and an aircraft (A4) cockpit viewing a rear projected screen. The future use of this simulator/trainer was investigated by an informal personal survey of Army and Navy labs by the Code 461-chaired JANAIR committee to determine potential military facilities which may have future use for the simulator. NADC Johnsville outlined the most promising program for use of the simulator, and reassignment of this simulator to Johnsville has been directed.

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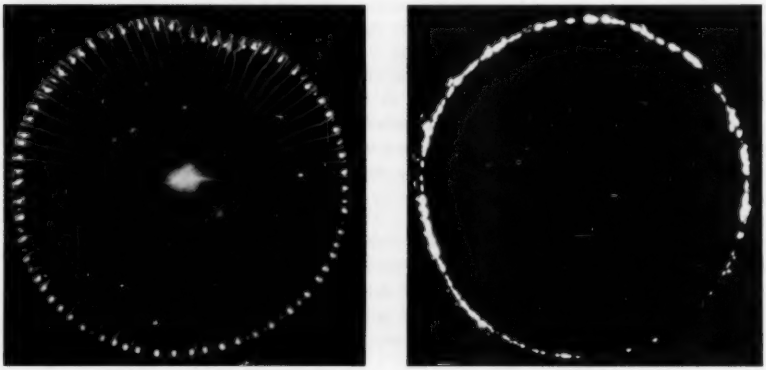
The Bioluminescent Protein "Aequorin"

F. H. Johnson
Princeton University

Specimens of the jellyfish *Aequorea aequorea* appear in such abundance every summer in the Northwest Pacific, especially in coastal waters of Washington and British Columbia, that they clog the nets of salmon fisherman and become a prime nuisance in general. Individuals (cover picture, Figure 1, and Figure 2) average about 3 inches and rarely attain a maximum of six inches in diameter. When mechanically stimulated, or sometimes spontaneously, they emit a bright bluish-green luminescence, a property of obscure usefulness to themselves, since they apparently lack organs of photoreception and therefore cannot detect visible light from other individuals of their own species or from any other source. Because their body is approximately 98 percent water and has a repugnant odor to man, they have no food value. When crowded in a sea water tank, they often try to eat each other with no sense of



(a) (b)

Figure 1 — (a) A single specimen of Aequorea *photographed by daylight in its natural sea water habitat, as viewed from the aboral surface. The mouth is indicated by the central, whitish mass, visible through the nearly transparent body, on the under side. The passage from the mouth leads to the radial canals and thence to the marginal canal at the periphery. The tentacles are shown in a contracted state as conspicious white dots along the marginal canal, with the much smaller photogenic organs difficult to discern between the bases of the tentacles. (b) A similar specimen, photographed by its own light in otherwise complete darkness.*

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Figure 2 — The body of a specimen of Aequorea, *pushed into the knot-hole of a piece of driftwood is used as a natural monocle*

proportion; smaller ones frequently try to swallow larger ones, sometimes partially succeeding, by a process of slow engulfing which takes hours or days.

These organisms were viewed as worthless by most people until 1961, when experiments by the present author sponsored by the Office of Naval Research revealed that the essential ingredient for light-emission in cell-free, aqueous extracts was a single organic component, a protein which was named aequorin. ONR's research on the bioluminescent protein of the *Aequorea aequorea* is just beginning to benefit medical science. This protein can be triggered to emit light only by calcium or strontium.* The discovery of this property opened the way to a new method for the microdetermination of calcium in biological systems with the advantages of sensitivity, specificity, and speed. The sensitivity extends in principle to as little as 10^{-9} molar calcium in a

*According to recent observations, as yet available only in the form of brief abstracts, J. W. Hastings has found suggestive evidence that systems similar to that of *Aequorea* can be extracted and triggered to emit light by addition of calcium, using the ctenophore *Mnemiopsis*, as well hydroids of *Obelia* as source of material. We have confirmed the results of his method of obtaining the active, crude extracts from *Mnemiopsis* and from hydromedusae other than *Aequorea*, but this method yields extracts which are much more difficult to purify than those obtained by our method from *Aequorea*, which method does not work with *Mnemiopsis*. Most recently (November, 1969), Hastings has reported the extraction of a particulate system from the sea pansy *Renilla* showing an activation to luminesce by addition of calcium or any of several other inorganic salts, and has advanced some speculations which, though as yet without adequate experimental evidence, constitute an interesting suggestion towards unification of a sequence of reactions in the luminescence of coelenterates (jellyfish, sea pansies, *etc.*) in general.

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small volume; its sensitivity to strontium is nearly as great, so in principle it could detect radio active strontium in a fall out. The protein's specificity is atested by its complete insensitivity to all other ions including magnesium, which is usually present and interferes in other methods. Aequorin's fast luminescence ability requires between a fraction of a millisecond to a few milliseconds at the most; the true situation is not yet established with full accuracy in publications.

The relevant Navy problems addressed by this research have to do with the biological effects in the ocean which might effect naval operations, and the biophysical principles on which organisms operate to achieve things which are beyond present technology but might be useful to the Navy. Specifically, the work seeks ultimately to provide understanding of bioluminescence which would permit us to create or prevent light production by the natural organisms in waters as suited or needed, and to isolate and characterize and employ usefully the biochemical products which create light from chemical action without heat.

Perhaps technological applications of bioluminescence may include self-illuminating documents, "cold light" for clandestine vehicles, controllable guidance systems for planes and watercraft, or for locating objects discharged by parachutes. If no technological applications develop, the work will fit into the medical support program since it will give new tools for biochemical and clinical research.

So far, the use of aequorin in the microdetermination of calcuim has found limited use, because of the difficulty in obtaining the material, unfamiliarity with the method, and lack of a general availability of expensive electronic equipment necessary for measuring the output of light. Otherwise the method should be useful in hospitals for blood calcium levels, public health laboratories for calcium content of various fluids such as milk, marine laboratories, agricultural laboratories, and many biological and medical research laboratories. We have furnished small amounts of aequorin to a few investigators interested in special problems, such as Dr. Britton Chance, who was in need of a rapid test for changes in calcium concentration in relation to activity of mitochondria, the results of whose study is scheduled to appear soon in a symposium volume to be published by Academic Press. Our supply of aequorin has been so limited that in fairness to our own work we have not been able to supply other investigators with the amounts they have needed for various types of physiological research. As a result, some investigators have gone to the Friday Harbor Laboratories to collect the jellyfish and prepare their own stockpile of aequorin. Prominent among them are Dr. E. B. Ridgway and Dr. C. C. Ashley who are the first to publish data obtained with the use of aequorin in living systems; in this instance they dealt with the changes in calcium concentration in the contraction of single muscle fibers (Figure 3).

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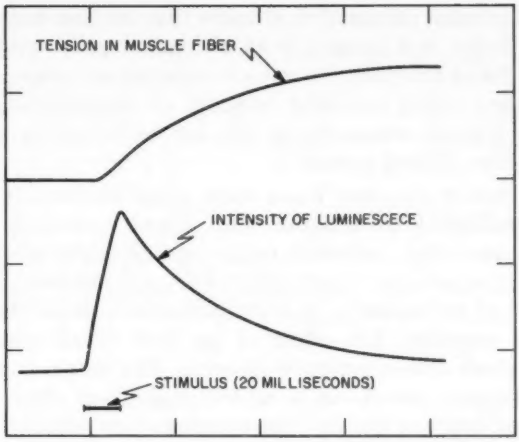

Figure 3 — Slightly smoothed curves from the data of Ridgway and Ashley (1967), the first published example of the use of aequorin as a test from calcium in a living system. A single muscle fiber of the barnacle Balanus nubilus *was micro-injected with partially purified aequorin which was allowed to diffuse through the fiber, causing no harm. Light emission of aequorin followed very closely after the onset of electrical stimulation, i.e., after a delay of about a thousandth of a second, and the development of tension after about 5 thousandths of a second. Following the initial excitation, tension in the fiber continued to increase after the cessation of the electrical pulse, at which time the light began to decrease. These data are averaged (by inspection) from five repeated experiments giving quantitatively close to the same results.*

Prior to 1961 a number of unsuccessful attempts had been made to obtain cell-free luminescent extracts from *Aequorea*, usually based on the assumption that the problem was purely a matter of finding an appropriate method of extracting a relatively heat-stable, specific substance, "luciferin" which functions as an oxidizable substrate, for a relatively heat-labile enzyme, "luciferase." The first example of a light-emitting reaction was reported in 1885 by Dubois, through research on the luminous click beetle *Pyrophorus*, of the West Indies; later Dubois reported an analogous reaction in extracts of the clam *Pholas dactylus*, indigenous to the Mediterranean Sea. These discoveries set a pattern of biochemical approach which was faithfully followed, with various modifications and refinements of technique, by different investigators such as Professor E. Newton Harvey for more than the next half century.

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From the present perspective, it seems that the time-honored, deeply entrenched belief that essentially all bioluminescence systems, though probably differing chemically from each other (except among biologically closely related types) consisted basically of "luciferin-luciferase systems," was a belief responsible in part for the long delay in discovery of the *Aequorea* type of system.

The anatomy of *Aequorea* cause some of the problems in the extraction and pruification of aequorin. The organs containing this photoprotein are very tiny, yellowish bodies, giving bright greenish fluorescence under ultraviolet "black light." They are situated on both sides of the bases of the tentacles, in a thin circumoral ring at the outermost edge of the organism. The center of the body is sub-spherical, or in some individuals almost perfectly spherical. The shape, combined with near transparancy, results in a natural magnifying glass (Figure 2). Despite their seeming fragility, the organisms are actually remarkably tough, being held together by strong connective tissue and cartilaginous material or gristle. They can thus withstand considerable trauma. Because of an ever-present slimy secretion which covers the whole body and the ability to suddenly flash on a light to startle a predator, the *Aequorea* is not totally helpless.

The first step, which is certainly one of the most efficient in the process of harvesting the photoprotein, consists in cutting off the thin marginal strip containing the photogenic organs. Ideally, the average volume of such a strip amounts to about 0.3 ml, compared to an average body volume of about 50 ml; so roughly 99.4 percent of the organism is discarded in this one step. Although most of what is discarded is water, other things are included such as unwanted proteins and much of the slimy constituents which would interfere with the purification procedures. For excising the rings, numerous devices were tried out in an effort to speed up production; but nothing worked as well as the laborious, painstaking use of a pair of scissors. Finally, a successful machine (Figure 4) which incorporated the best ideas of several investigators was designed and constructed. Two machines were used to great advantage during the summer of 1969 at the University of Washington's Friday Harbor Laboratories.

With the help of local teen-agers and regular or special assistants, we have collected and "de-ringed" approximately 125,000 individual specimens of *Aequorea* during several summer seasons at Friday Harbor. This amounted to more than six tons, before processing. With continual improvements in methods, we now expect to obtain more than 100 mg of pure aequorin from perhaps 25,000 specimens. The biochemical procedures are simple and straightforward, but the final yield is still not high enough. Aequorin undergoes very slight deterioration when stored in saturated ammonium sulfate solution containing EDTA (ethylenediamine tetraacetic acid) in an ordinary refrigerator.

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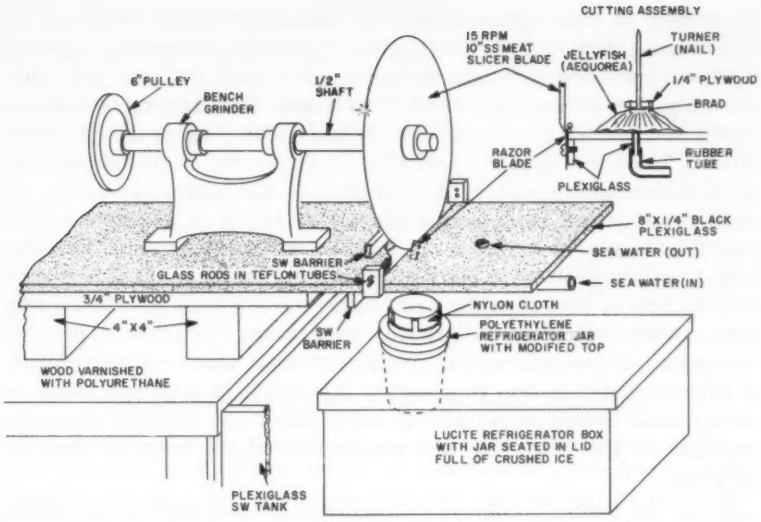

Figure 4 – Machine used in "de-ringing" specimens of Aequorea, *by first positioning them over inflowing sea water, which also inflate the body somewhat by filling the internal canals, then, with the aid of a "turner," rotating the specimen against a razor blade juxtaposed against a slowly moving meat-slicer blade. The black plexiglass platform aided visibility of the internal organs, though careful observation during the cutting process was usually not necessary because the teflon-covered horizontal glass rods (held at the positions indicated but not fully shown in the figure) prevented more than a narrow edge of the specimen from reaching the blades. The platform was slightly tilted so that sea water drained towards the opening just beyond the cutting edges. The excised rings were thus washed gently into a receptacle which was kept immersed in crushed ice. The overflow from the receptacle drained through a nylon cloth collar which prevented the escape of the rings.*

A small portion is easily removed by centrifugation at refrigerator temperatures. It gradually loses its luminescence activity, however, at room temperature.

The light-emitting reaction of aequorin with calcium results in a spent product which, when observed under ultraviolet light fluoresces with almost precisely the same emission spectrum as that of the bioluminescence reaction. A functional moiety in the essentially non-fluorescent aequorin (prior to the reaction with calcium) can be biochemically separated from aequorin, but only at the expense of the active protein, and unfortunately the fluorescent moiety cannot as yet be separated from the fluorescent product after the reaction with calcium.

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According to mass spectrometry, the molecular weight (MW) of the fluorescent moiety is 277, whereas that of aequarin, according to several methods, including critically accurate amino acid analyses and ultracentrifugation, is between 30 and 32 thousand. Thus 100 mg of aequorin would be expected to contain scarcely more than 1 mg of the functional moiety. Since this moiety is undoubtedly the source of the light emitted in bioluminescence and in fluorescence of the aequorin system, its chemical structure is of special interest. If 10 mg of the moiety were available, it should be relatively easy to arrive at the structure; with only 1 mg, the problem is much more difficult. In any event, it is reasonable to believe that once the exact structure is known, successful synthesis should follow soon afterwards and perhaps it will then be possible to produce, by conjugating the synthetic product with a suitable protein, a semi-synthetic system functionally equivalent to aequorin. Such an achievement would eliminate the work, time, and expense presently required in the extraction and purification of the material from the jellyfish.

From the point of view of the authors, the aequorin test is purely incidental, not at all the most important outcome of our experiments with this system. There is reason to believe that research on the aequorin photoprotein† and other systems including the enzyme system of the little ostracod crustacean *Cypridina* from Japan may provide the key to a wider understanding of bioluminescence reactions in general. And more important still, the research which has revealed the nature of the aequorin system may have opened the gates to new, fundamental knowledge concerning biological reactions involving single proteins. As in the emission of light from aequorin these reactions may release relatively enormous amounts of energy, up to some 70,000 calories. These reactions remain unknown at present because the release of such energy is so rarely in the form of visible light, and no natural indicator exists to reveal the occurrence of the reaction.

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†In addition to the *Aequorea* system, two other photoprotein systems are now know, *viz.* those of the "paddleworm" *Chaetopterus* and of the euphausiid shrimp *Meganyctiphanes* ("krill") which we have described in several technical publications beginning in 1966. Profound biochemical differences characterize these three, but they are alike in two basic respects; (1) the light-emitting reaction does not involve direct participation of an enzyme, and (2) the total light emitted under optimum conditions is proportional to the amount of the specific protein rather than (as in luciferin-luciferase systems) being proportional to the amount of an easily diffusible molecule acting as a substrate for an enzyme. Of these two properties, the first is probably the most important, inasmuch as all bioluminescence systmes involve at least one protein component, whereas in the final analysis the distinction between photoproteins containing a functional group, (as in aequorin), on the one hand, and luciferin-luciferase systems on the other hand, may depend simply on the tightness with which the functional group, or the substrate as the case might be, is bound to the protein.

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Antibacterial Effects of Hyperbaric Oxygen

A quantitative method of determining the bactericidal effect of hyperbaric oxygen by direct exposure of small inocula on the surface of solid media has been developed at the Louisiana State University School of Medicine, New Orleans, Louisiana. This method is being used with defined growth media supplemented with vitamins, minerals, and other growth compounds to ascertain those compounds able to overcome antibacterial effects of hyperbaric oxygen at 3 atmospheres absolute or less. Results indicate to date that oxygen toxicity for bacteria represents a metabolic disturbance which can be overcome by means of nutritionally enriched growth medium.

Geographic Orientation in Aircraft Pilots

An extensive effort conducted for the ONR JANAIR working group on Geographic Orientation in Aircraft Pilots by Human Factors, Inc., has been concluded by the publication of two final reports and an ONR Conference (18-20 November 1969) entitled "Geographic Orientation in Air Operations." Conference Report will be published in June 1970.

The contract effort resulted in a list of cartographic feature selection criteria biased towards the low level fast attack mission and demonstrated the effectiveness of charts produced by using this criteria when compared to present cartographic systems. The technical reports provide the basis for the development of an inter-command position on the requirement of a defined special chart series for use in projected map displays.

Research Program of the Stevens Institute of Technology

The Davidson Laboratory of the Stevens Institute of Technology has just completed one phase of a research program dealing with the hydrodynamic impact of planning hulls. The results are presented in a report entitled "Engineering Approximation to Maximum Accelerations Experienced by Planing Craft in Rough Water," by J. K. Roper, SIT Report 1437, December 1969. In this report, an engineering procedure for estimating maximum accelerations on planing hulls in irregular head seas has been developed using a combination of present understanding of the fundamentals of impact theory, full-scale and model test observations of planing hulls in waves, and a judicious selection of approximations. The method is readily explained in operational terms, easy to apply, and produces results of sufficient accuracy to be useful from an engineering standpoint. Good agreement is obtained between computed and measured maximum center-of-gravity and bow accelerations for a series of round bottom and hard chine planing hulls tested in simulated state 3 and state 5 seas.

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Laser Glass

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The following summary of the status of laser glass development was given by the author as part of his charge to the National Materials Advisory Board Ad Hoc Committee on the Fundamentals of Damage in Laser Glass. The committee was set up under ARPA-ONR (Advanced Projects Research Agency) sponsorship to provide guidance and recommendations on how best to proceed in an attempt to solve the problems currently facing the laser glass industry.

Since laser action in glass was first demonstrated in 1961 the military has had a considerable interest in the development of laser glass and has provided a substantial fraction of the support for the development of glass laser materials. The current situation is such that we are encountering optically induced damage problems which pose a serious threat to widespread military use of laser glass devices. Although this problem has been with us for a number of years, and some considerable effort has already been directed toward solving the problem, it is not at present clear that either of the two approaches currently being followed will yield totally satisfactory solutions to the problem or whether these solutions represent the best that can be found. In fact, it is not totally clear what the source of the presently observed damage is.

Starting in early 1962, several glass companies were commissioned to undertake a broad program for the study of laser glass which included among other things, the melting of well over a thousand different Nd laser glass compositions. Such properties as lifetime, line width, quantum efficiency and gain coefficient of these glasses were measured. Surprisingly, they showed, with a few minor exceptions, that the laser properties were not extremely sensitive to the host composition.

Soon after moderate-sized Q-spoiled glass lasers were operated, catastrophic internal damage was observed. Similar damage was observed in high-power long-pulsed laser systems. This damage was traced to random inclusions of platinum from the crucible; (all optical glass-making facilities in this country have been converted to platinum since the last war due to the much better optical quality obtained with this method). Platinum particles as large as 50-100 microns were often observed with a higher distribution density of smaller particles decreasing in size to beyond optical resolving power. Local heating at the site of the platinum inclusion, caused by the intense laser beam, results in stresses exceeding the breaking strength of the glass. Further investigation revealed that the platinum particles arise both from chunks of the crucible included in the melt and from the recrystallization of platinum dissolved in the melt. Solutions to this problem were sought both by using a reducing atmosphere to control the rate of attack on the platinum crucible and by returning to refined versions of the ceramic melting techniques used many years earlier.

Inclusion damage has been the most serious source of difficulty although surface damage and a damage associated with self-focusing of beam trapping have contributed additional problems for the systems engineer. Surface damage

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is strongly dependent on the cleanliness of the surface, but also appears to be somehow associated with the dielectric discontinuity at the surface. Damage thresholds have been raised both by etching a porous surface layer and by water immersion. While a great deal of information regarding the success of these techniques at extremely high power density is not yet available, it would appear that the surface damage problem is to some extent amenable to engineering solution. Self-focusing, if it is due to electrostriction, should be an intrinsic property of the host glass and the damage threshold would not be likely to change appreciably from glass to glass. On the other hand, if the focusing were to be caused by an absorption process, sizable variations could be expected depending on the base glass and impurities. Preliminary data seems to indicate that the focusing threshold is between 50 and 100 joules/cm^2 Q-switched and does not depend strongly on the base glass composition.

Currently the glasses available exhibit thresholds for damage from 10 to 40 joules/cm^2. Lithia Alumina Silicate glass melted in platinum-iridium crucibles under a controlling atmosphere damages at approximately 20 joules/cm^2. This glass contains some small platinum inclusions whose number and size industry is hopeful of reducing. How far this platinum reduction can be pushed is not clear nor is the size reduction required in order to cause "other centers" to become the major contributor of bulk damage known. Although industry may have given some consideration as to whether their composition is the best from the point of view of reducing platinum inclusions in high optical quality melts, there has been little open discussion of the effect of composition on inclusion concentration. While the previously mentioned composition yields a glass that has somewhat superior characteristics compared to other laser hosts, these advantages would not necessarily outweigh the advantage of going to a composition that could be melted so as to be more damage resistant.

The French, melting a Barium Crown glass in a ceramic crucible, are marketing a glass exhibiting a damage threshold of over 40 joules/cm^2. A United States company, producing essentially the same composition in a ceramic crucible, is having trouble obtaining glass showing a threshold for damage of 20 joules/cm^2. Available evidence indicates that inclusions from the ceramic pot are a source of damage centers. Both France and the U.S. use active laser probing techniques to eliminate those pieces having major flaws which lead to extremely low damage thresholds. Such selection techniques are laboriously slow and expensive to carry out, especially in light of the relatively low yield of good glass that is currently being obtained. Little or no knowledge is available on the yield of the French glass. Originally they were melting in 30-50 pound batches; however, recently they have gone to 500kg batches which normally could be expected to increase the yield of good glass. Again, it is safe to assume that the Barium Crown glass has not been demonstrated to be the best glass for melting in a ceramic system. Consideration of other compositions should be given.

It is by no means absolutely clear that the damage in ceramic laser glass arises from stones or other inclusions from the pot. Impurities in the raw materials or coming from the crucible itself may be a significant source of this damage. It is not clear that inclusions are the only source of damage centers. We have observed cases where a lens of Shott SF-4 glass which is melted in large ceramic pots has stood up for 25 shots under extremely intense illumination, and then totally disintegrated on the 26th shot. Perhaps the intense laser beam is pro-

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moting a devitrification of the glass or a combination of nonlinear focusing onto a weak spot in the glass led to the failure. What is clear is that by focusing down inside a glass sample, bulk damage thresholds of 4-500 joules/cm² can be observed. Apparently, on a somewhat random basis, centers of much lower strength exist. When these are illuminated in a uniform high energy laser beam, damage occurs at a much lower energy threshold. Understanding these mechanisms will be an important step toward achieving better laser glass.

Having looked at some of the damage problems, let us now give consideration to what the systems engineer may desire or require. First of all, experience seems to indicate that if a rod withstands a few trial shots at twice the energy density desired in operation, it will generally have a very good life expectancy. Therefore we should aim to fabricate glass that will withstand twice the energy density the systems engineer will normally require. Secondly, fabricating rods in order to test them is a time consuming and expensive procedure which may be suitable for a one of a kind device, but is hardly desirable for a large production item if the yield is low. Therefore, we should attempt to come up with a method of producing a high yield at the required damage threshold.

One is tempted to speculate that with a damage threshold of even 10 joules/cm² and rod diameters of 3 inches one could achieve power outputs of 400 joules per pulse without damage, which should cover most of the major military applications. This assumption is invalid from two points of view. First, the pumping of such large systems places undue stress on the flash lamp, as the entire volume must be pumped to a level well over threshold. This becomes even harder as the doping density is reduced in order to achieve uniform pumping across the rod. Secondly, for systems requiring any reasonable average power, the large diameter presents formidable cooling problems which force us to go to such things as segmented face cooled disk systems.

From an efficiency point of view, the engineer would like to operate at or a few times above the saturating energy density. For straight Nd this is ~10 joules/cm² but for the Nd Yb glass, where the life is 4Ms the saturation energy is 40 joules/cm². Even for the "flea powered" laser, it would be desirable to operate at these energy densities. From these considerations, one concludes that the ability to make glass having a damage threshold of 100 joules/cm² with a high yield is extremely important to the incorporation of glass laser systems into military equipments. Our task is to find out what problems will have to be overcome to enable us to produce high durability laser glasses and to outline an expedient program for achieving these ends.

Stabilization of Plague Vaccine

The plague vaccine for use in preventive medicine is evaluated in comparison to a whole bacterial suspension which has been dried from the frozen state and stored at 4C° under nitrogen. A study is underway at the Naval Biological Laboratory to find the effect of drying under various conditions and with various additives on the capacity of the vaccine to protect mice against subcutaneous challenge with virulent *Pasteurella pestis* bacteria. The results to date show that when the vaccine was dried without additives at terminal temperatures of 2, 25, 50, and 80C°, the loss in potency after storage for one year at room temperature was related to the drying temperature. The 50% protective dose of vaccine dried at 50C°.

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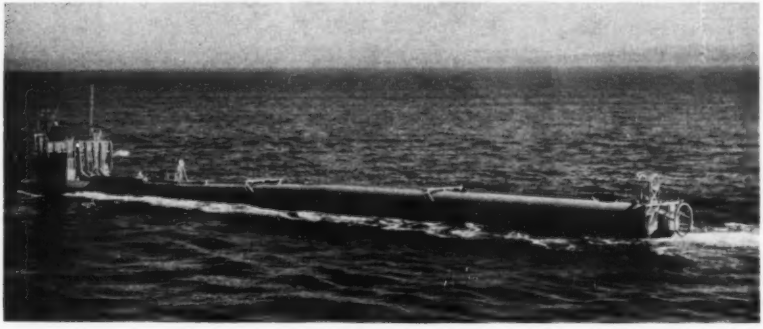
Research Notes

FLIP Updated

The Research Platform FLIP has been in the limelight lately; therefore, it seems appropriate to review briefly what FLIP is about and to describe her encounter with the heavy seas at PARKA II station. FLIP is owned by the Navy and operated by the Marine Physical Laboratory (MPL), Scripps Institution of Oceanography (SIO), and the University of California under ONR contract.

FLIP, standing for Floating Instrument Platform, is designed as a super stable, open-sea, free-floating platform from which to conduct research in the field of physical oceanography—primarily underwater acoustics to a scale previously impossible due to background noise and platform motion.

FLIP has a long slender tubular hull 20 feet in diameter for about half its length then tapering to 12.5 feet in diameter as the bow is joined. The overall length is 355 feet and the vertical displacement is approximately 2000 tons. The draft is about ten feet in the horizontal tow position and about 300 feet in the vertical position.



The flipping operation from horizontal to vertical results from controlled flooding of tanks in the after two-thirds of the platform during which the bow rises and the stern drops until she floats in a vertical position. All three generators, the air compressors, and the MK 18 gyro-compass are mounted on gimbals and made up with flexible connections so they may be operated in both the vertical and horizontal positions.

Working and living spaces include the engine room, living quarters, electronics labs, and a wet lab area, all in the bow section plus converted tank No. 10 (adjacent to the bow section) which contains a pump room, electronics, berths, and air compressors. The control platform (vertical) and the main deck (horizontal) form the operating area. All flipping controls may be manipulated from either position. A hydraulically operated orientation system is installed. B-end motors drive propellers at the 250-foot level to maintain orientation either manually or automatically.

FLIP has an oceanographic winch, an electric capstan, booms, and mountings on the bow section, at the stern, and at the 100-foot and 200-foot submerged points for handling various sonar arrays, scientific instrumentation, and other equipment to be tested or used for data gathering.

Because of vertical stability and simplicity of design and operation, FLIP has exceeded by far expectations for her utility as an oceanographic platform. FLIP has conducted

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about sixty scientific expeditions engaging in such research as measuring microsale energy processes, sound propagation, sound bearing accuracy, wave attenuation, wave pressure and acceleration measurements and measurements of internal waves by means of a thermistor chain. FLIP has spent almost 600 days at sea in her seven year life and has performed the transition from horizontal to vertical and return more than 150 times. FLIP has conducted operations as long as 45 days in duration. In an operation in the Gulf of Alaska during which gale force winds and seas to 35 feet were encountered, the average vertical oscillation was measured at less than three inches. Sea keeping characteristics while under tow are good and towing speeds are limited only by capabilities of the towing vessel and towing tackle.

FLIP operations during the past year have included PARKA I, BOMEX, bearing accuracy experiments with the Naval Ordnance Laboratory's (NOL) SPAR north of Puerto Rico, and recently PARKA II-A. On 1 December while moored at PARKA II station during a period of very rough seas a series of anomalous waves (some reportedly as much as 50 feet in height) rolled over FLIP causing some flooding damage to electrical equipment, bent and carried away various external appendages, and parted her mooring. Although there were personnel on deck securing a boat which had broken loose, there were no personnel casualties. Sea state has been running state 8 prior to this event and the ship was already thoroughly buttoned up and blown up about 10 feet higher than normal.

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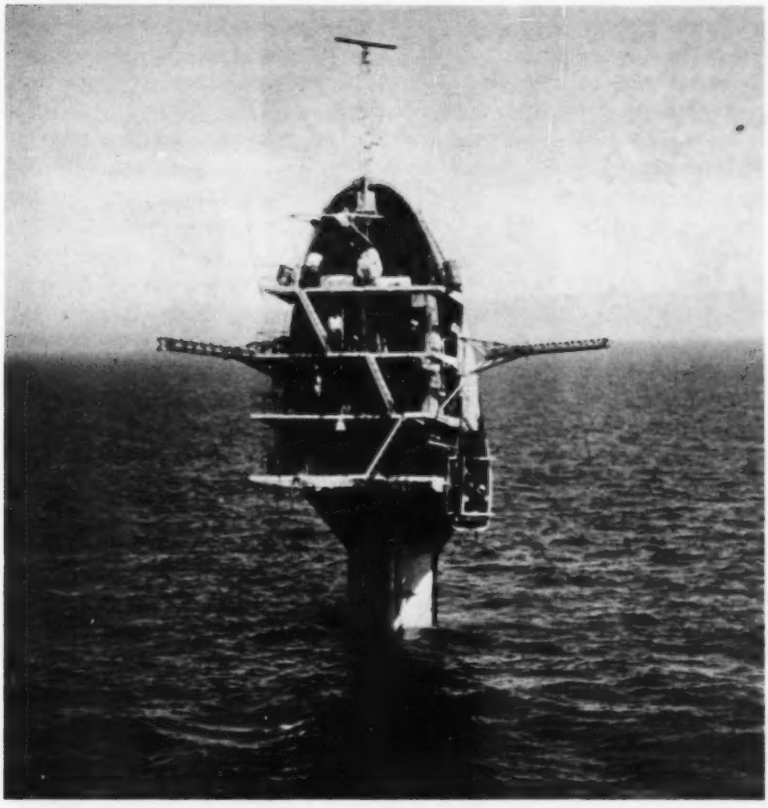

However, a stand pipe *ventilator* collapsed under the force of the first swell providing a large access to the sea and permitted the later flooding. Personnel on deck sought cover at the upper platform level and, when subsequent swells of 15-20 second period induced plunging, water reached waist-high depths at the upper level. Dr. Sykes of Code 468 was in the PARKA area during this time. FLIP entered Dillingham Shipyard at Pearl Harbor for clean-up and repairs and will be ready for PARKA II-B in late February. In order to prevent future recurrences of this type closure ventilation fittings are being installed at the hull.

Octopods from the Deep

The Naval Research Laboratory Scientists photographed these odd-appearing creatures at a depth of some 13,000 feet in waters off St. Croix, Virgin Islands while on an ocean engineering mission for the Navy.

Dr. Clyde F. E. Roper, Supervisor and Associate Curator, Division of Mollusks, Smithsonian Institute described the specimens in the photos as finned or cirrate octopods. They belong to the Order Cirrata, primarily deep sea octopods of which little is known.

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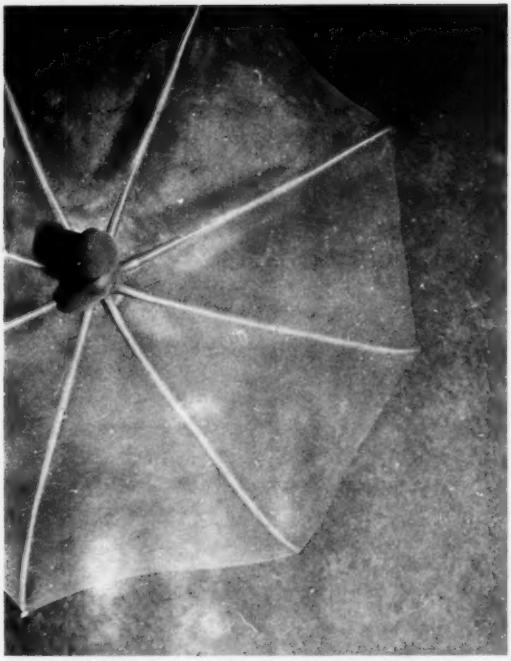
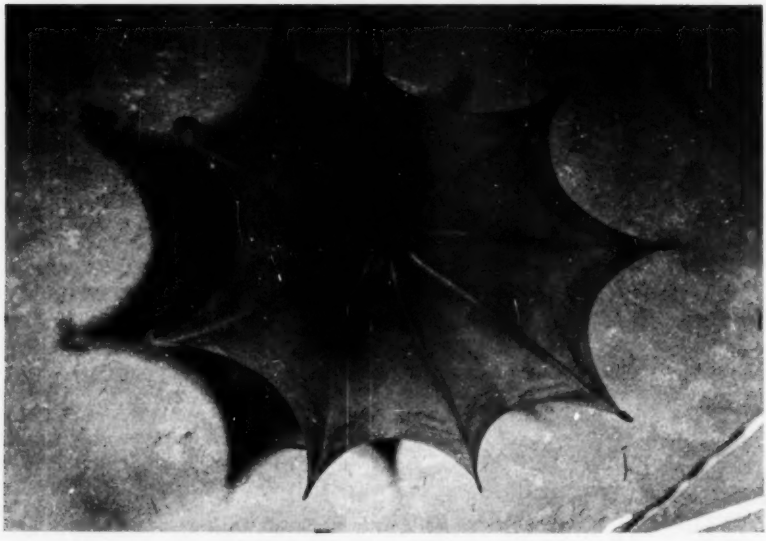


Length from tentacle to tentacle in diameter is 24 1/2 inches



Octopod 48 inches in diameter

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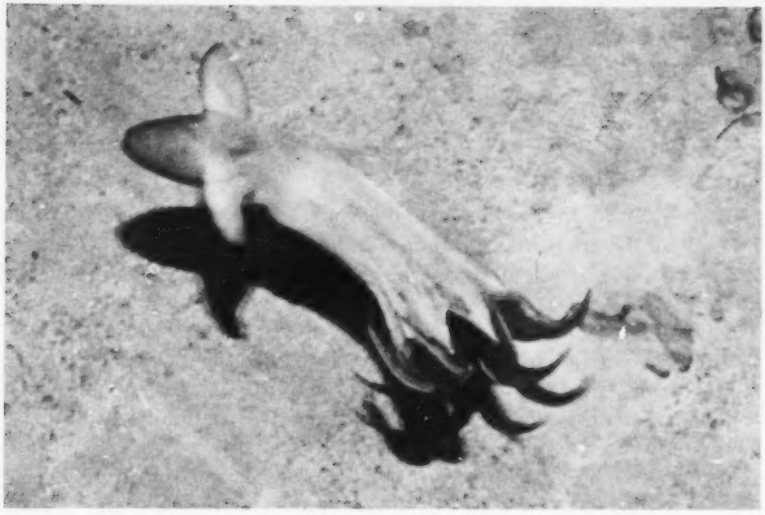

Swimming Octopod

In speaking of the photos Dr. Roper said their exceptional quality will allow tentative familial (or even generic) identification and more accurate estimates of size. Because of the absence of good selections of the specimens, little had been understood about their classification (*e.g.* the numbers of different species and relationships to each other) and even less was known about their biology and habits. Some of the photos show the octopus with its eight arms stretched out perpendicular to the body axis; a thin, filmy web connects the arms and in this position the animal looks somewhat like an open umbrella. (One of them measured 48 inches across from tenacle to tenacle according to the scientists measurements.)

The soft, sac-like body and head occurs above the outstretched arms and web. The other specimen, Dr. Roper said, shows a finned octopod in swimming position—very possibly swimming away to escape the approaching camera. The fins are outstretched and one eye can be seen as a dark spot just ahead of the lower (right hand) fin. The arms are folded up and trail "behind" the animal. (Since octopods generally swim backwards, their heads, and arms trail their bodies; they walk or crawl and attack their prey frontwards). Dr. Roper and Mr. Walter L. Brundage, Jr., an Oceanographer with the Naval Research Laboratory, who was on the St. Croix Mission, will make a scientific report on their findings from the photos in the near future.

Interestingly, the photographs were made from 35mm underwater cameras mounted on a towed-vehicle conceived and built by NRL scientists dubbed the "fish." The "fish" became internationally known when it was used to locate the two nuclear submarines, Thresher and Scorpion, the lost H.bomb off the coast of Spain and more recently the lost research Navy Submarine Alvin. The "fish" is towed by the USNS Oceanographic Research Vessel the Mizar which is operated by the Military Sea Transportation Service. The versatile research instrument is loaded with electronic devices including the cameras, strobe lights, a magnetometer, a television camera, a transponder, a side-looking sonar, a pinger and a telemetry system.

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On the Naval Research Reserve

NRRC 1-1

Rear Admiral Joseph C. Wylie, USN, Commandant, presented the First Naval District Phased Forces Trophy to Naval Reserve Research Compnay 1-1 in a short ceremony at the Naval Reserve Training Center, Boston, Mass.

Naval Reserve Research Company 1-1, now in its twentieth year, was founded in part to provide a pool of qualified manpower to support the Office of Naval Research in times of national emergency. The Company has drawn heavily on local educational institutions, as well as industry for its membership, guest speakers at drill programs, and for field trips. It has sponsored several three-day periods of ACDUTRA in recent years, as well as two-week summer seminars at the Naval War College, Newport, Rhode Island.

During the past year the Company sponsored a Foreign Policy week-end seminar at Bentley College. Eminent speakers from the Fletcher School of International Diplomacy, Harvard University, and U.S. Information Agency, discussed our present United States international relations. Beyond these activities, several members were active throughout the year preparing the two-week "Advanced Naval Technology" seminar which was presented at the Naval War College, Newport, Rhode Island.

NRRC 1-5

Naval Reserve Research Company 1-5, Worcester, Massachusetts, held its twentieth anniversary dinner. The company was founded in October 1949 with 20 members under the sponsorship of Worcester Polytechnic Institute.

Captain Carl O. Holmquist, USN, Deputy Chief of Naval Research, flew in from Washington to participate in the anniversary celebration. Following the dinner, he spoke on the research expenditures of the Navy—past, present, and future. He demonstrated the tremendous task of managing a major project by discussing the F-14 aircraft which should make its maiden flight in 1970. This project has been kept on schedule and set records for progress through careful, thorough planning and good management.

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NRL Forms Pollution Control Staff

The Naval Research Laboratory, has established an Environmental Pollution Control Staff. The new Staff will serve as a central coordination group for the various sections at the Laboratory now involved in the control of contamination and conduct research for new and improved methods to be used in the fight against pollution.

Captain James C. Matheson, Director of the Naval Research Laboratory, said he established the Staff to insure that NRL will meet its responsibilities in helping to clean up the nation's environment. He added that the Laboratory recognizes that pollution of the environment is of growing public concern and that prompt and serious attention must be focused on the problem if it is to be controlled.

The Laboratory has over forty years of experience in research on the effects of contaminants on the habitability of submarine atmospheres and has gathered much valuable information which may be useful in helping to resolve other environmental problems.

Mr. Victor R. Piatt, who has been coordinator of the Laboratory's nuclear submarine atmospheric habitability program for the past twelve years, has been the author or editor of twelve significant status and progress reports in the field.

Aristides Stamulis, who has specialized in defense against certain chemical agents will assist Mr. Piatt. Ralph C. Taylor, a nationally-known plastics and rubber chemist, will serve as consultant on disposal of surplus of waste chemicals. A mechanical engineer will be added to the Staff later. The Environmental Pollution Control Staff will report directly to the Associate Director of Research for Materials, Dr. J. H. Schulman.

Mr. Piatt said early efforts of the Staff will study existing pollution control requirements and standardize existing disposal methods for waste materials. He added that there is a possibility of development of a novel chemical incinerator to dispose of the waste.

Succeeding efforts of the new Staff will include establishing stricter pollution-control standards for the Naval Research Laboratory than required elsewhere, and performing research on air and water pollution problems of special interest to NRL or other Navy activities. All of these efforts will be supported by existing chemical and physical research teams and equipment at the Laboratory.

NAVAL RESEARCH REVIEWS publishes highlights of research conducted by Navy laboratories and contractors and describes important naval experimental facilities. Manuscripts submitted for publication, correspondence concerning prospective articles, and changes of address, should be directed to Code 109, Office of Naval Research, Washington, D.C., 20360. Requests for subscriptions should be directed to the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402. Subscription price: $1.75 per year in the U.S. and Canada; $2.25 per year, foreign; $0.20 per individual copy. The issuance of this periodical approved in accordance with Dept. of the Navy publications and printing regulations.

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